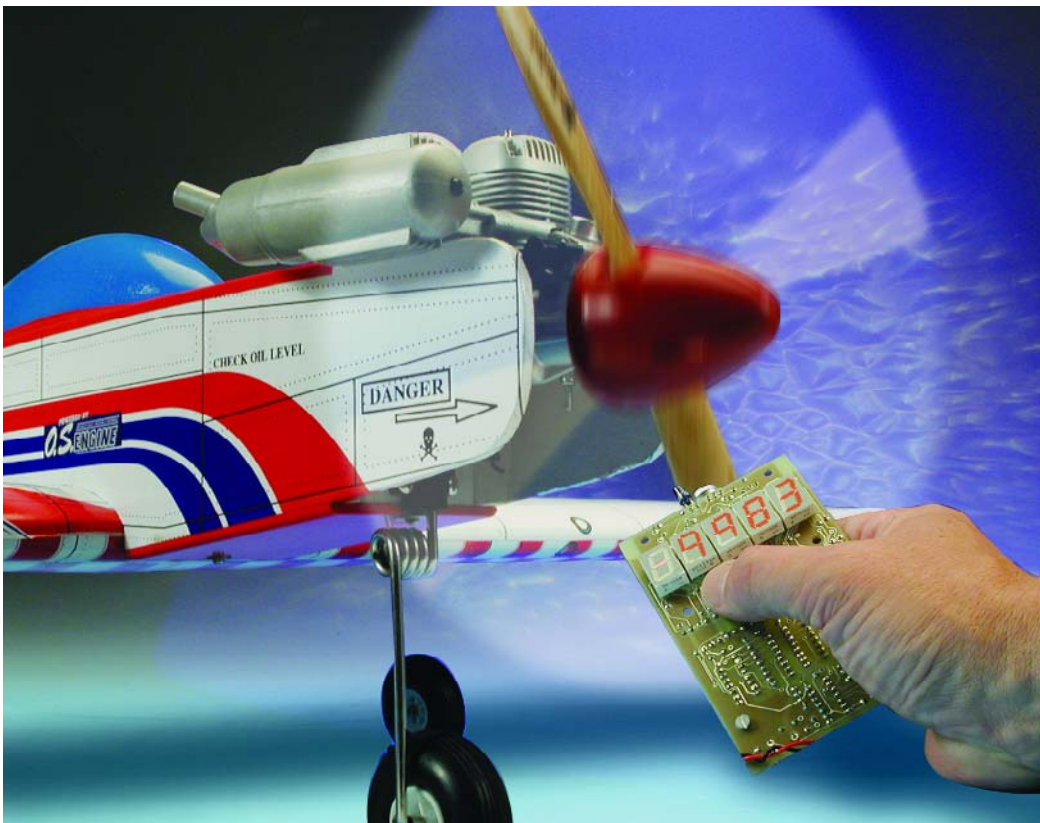


Rev Counter for R/C Models

Using an optical sensor

Design by P. Goossens

The engines used in modelling have to be carefully tuned if they are to run at their best. An important measurement is the engine speed at full power. This circuit can be used for such measurements, as long as a propeller is driven or a marker line is visible.



If you want to obtain the best performance from a model engine, it is essential that the engine speed can be measured accurately.

With the help of a good rev counter the carburettor can be adjusted correctly at full power and engines can

be compared with each other. This can become quite complicated, since the type of propeller, fuel, glow plug, etc, all affect the maximum engine speed.

The use of the rev counter described here isn't limited to measuring the engine speed of model airplanes. In principle, you can draw a white line on any drive shaft and then measure the rotational speed using this circuit. If the drive shaft is shiny, it is better to draw a matt-black line. The practicalities of taking measurements will be covered in detail later.

Sensor

In normal petrol engines the engine speed is easily arrived at by measuring the frequency of the pulses to the spark plugs. Unfortunately, the engines in the modelling world use glow plugs instead of spark plugs, so this method cannot be used. We there-

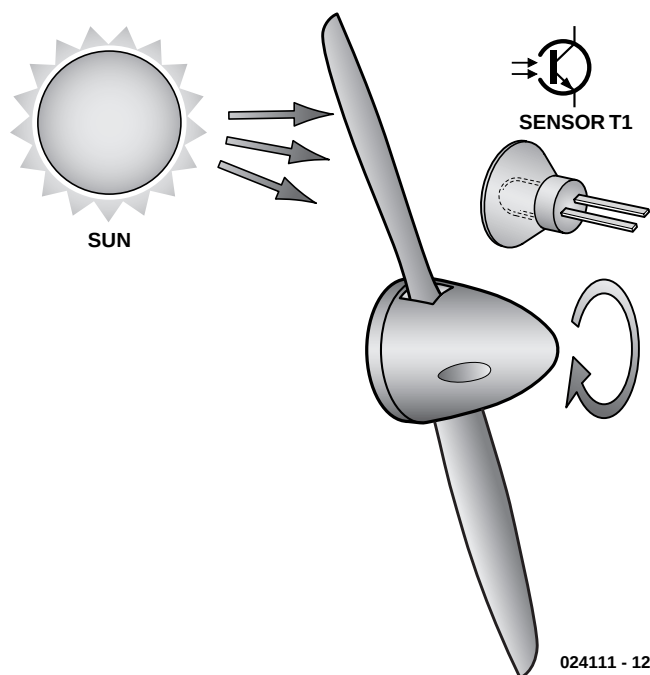


Figure 1. The light/dark transitions of the sunlight are picked up by the sensor.

fore have to look for a different solution. It would be ideal if no special parts had to be mounted inside the airplane, since the last thing you want is to increase the weight of a model airplane.

Most model airplanes still use a propeller that is driven directly by the crankshaft of the motor. The rotational speed of the propeller is then equal to that of the engine. If we now hold an optical sensor in front of the propeller such that the shadow of the blades falls across the sensor, we can measure the frequency at which the blades rotate (see **Figure 1**).

This method does require sufficient background light, because the difference between light and shadow has to be big enough for it to be detected by the sensor. When there is too little background light, it's very easy to give Nature a helping hand. Just to the side of the sensor of the rev counter we add an IR LED, which doesn't illuminate the sensor directly, but which emits infrared light in parallel towards the propeller. The blades of the propeller will reflect this light back periodically to the sensor, which can be measured (**Figure 2**).

Measurement

The frequency of the signal from the sensor is directly proportional to the engine speed. With a two-bladed propeller the light intensity will change twice per revolution, with a three-bladed one three times, and so on. From the frequency of these interruptions it is possible to calculate the number of revolutions per second. However, a rev counter normally shows the number of revolutions per *minute* and not per second. That means that we still have to multiply the shaft frequency by 60 to obtain a value for RPM (revolutions per minute).

Fixed measuring time

Right then, to start with we have to measure a frequency. There are two standard methods used for this. The first is to count the number of pulses that occur during a fixed period of time. The measured frequency is then obtained using the formula:

$$f = \frac{\text{measured number of pulses}}{\text{time}},$$

where the time (in seconds) is con-

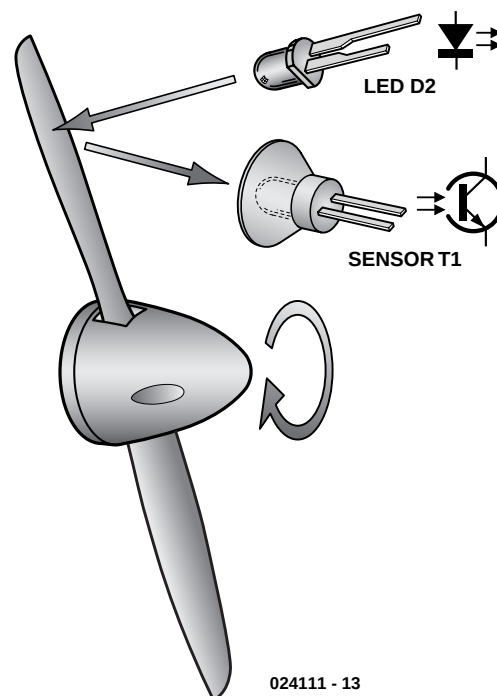


Figure 2. The light from an LED is reflected from the propeller blades and then detected.

stant. If we take a fixed period of 1 second, the accuracy of the measurement will be ± 1 Hz. In our case, this frequency has to be multiplied by 60 and divided by the number of propeller blades.

For a two-bladed propeller the accuracy would become:

$$\pm 1 \text{ Hz} \times 60 / 2 = \pm 30 \text{ RPM}$$

If possible, we would like to have a resolution of one RPM. (Note that this is not usually provided, since most rev counters show a value $\times 100$, so the resolution is then 100 RPM). Simply increasing the measurement time by 30 will give the required resolution. Unfortunately, this also means that the measurement is only updated twice per minute. This is unacceptably slow, so this method cannot be used.

Fixed number of pulses

Another method is to measure the time taken for a certain number of pulses to occur. This method is therefore the exact opposite of the previous one. The frequency is now calculated as follows:

$$f = \frac{\text{pulses}}{\text{measured time}},$$

This measurement is most accurate at lower frequencies and becomes progressively less accurate at higher frequencies. The resolution

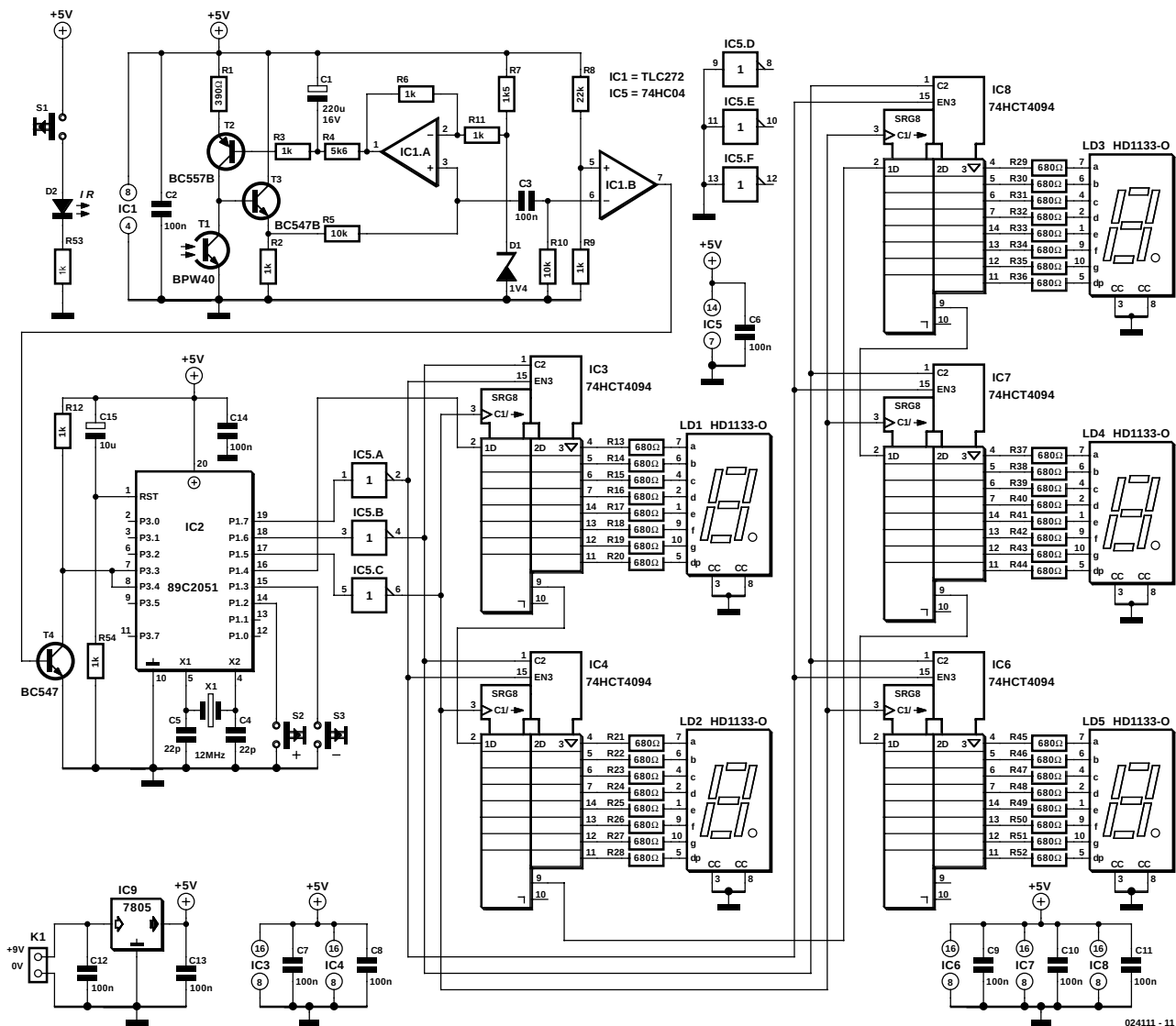


Figure 3. The circuit consists of three sections: the sensor, the controller and the display.

here depends on the number of pulses counted (constant), the accuracy of the time measurement, the frequency to be measured and the number of blades on the propeller. To give an acceptable accuracy over the whole range, a large number of pulses are required for this method, which results in a long measuring time at low revs; this isn't ideal either.

A different way

We can conclude that neither of the previously mentioned measurement techniques is suitable for our purpose, so some other method has to be found. In the end we used a technique that is really a combination of the two, but without their disadvantages.

The measurement starts when the first pulse is detected by the sensor. During the next second the number of pulses is counted. After this second has passed, we wait until

final pulse is detected. The frequency can then be calculated using the formula:

$$f = \frac{\text{measured number of pulses}}{\text{measured time}},$$

From this it can be seen that *both* variables have been measured, combining the advantages of both methods described earlier.

The circuit

The circuit (**Figure 3**) can be divided into three sections: the sensor circuit, the controller and the display. The sensor circuit (built round IC1) uses a BPW40 as the light-sensitive device. This is in fact just a transistor without a base connection, where the die has been left exposed

to the light. The more light that reaches the die, the more the transistor conducts.

IC1a tries to keep the voltage on pin 3 at about 1.4 V. Should the voltage rise above this, the output of the opamp will also rise, as will the voltage at the base of T2 after a short delay. This results in a reduced current flow through T1, which in turn reduces the voltage on pin3 (via buffer T3).

R4, C1 and R3 form a low-pass filter, slowing down the regulation. This causes the average voltage on pin 3 to be 1.4 V, but fast pulses (such as the shadow of a propeller blade) are not smoothed out. IC1b functions as a comparator, which converts the pulses into a logic level for the processor.

IC2 is an old favourite of ours, the 89C2051. This controller barely requires an introduction, since it has often been used in Elektor Electronics circuits. In this circuit a simple program takes care of the pulse measurements, driving the display and reacting to pushbuttons S2 and S3. Since this controller has an internal flash memory for the program, there is no need for an external EPROM, address decoder and associated logic gates. This keeps the controller section very compact. IC2 is available fully programmed, but you can also program it yourself using the software that is available separately on floppy disk.

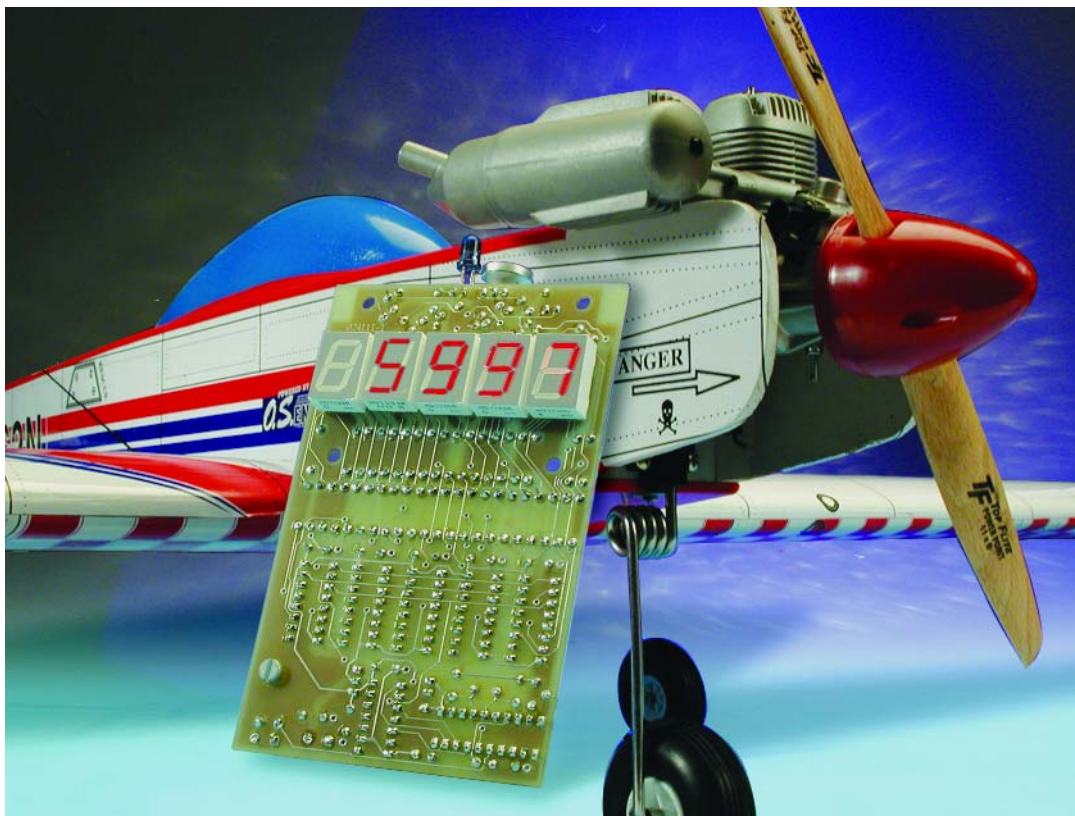
IC5 is used as a buffer for signals from the controller. These signals are used to drive the serial shift registers (IC3, IC4 and IC6 to IC8). The outputs of these shift registers drive the displays directly (LD1 to LD5).

For the displays we recommend the HD1133 O-K. These are bright enough at a relatively low current. Other common cathode types with the same pin-out can also be used of course, but you may have to change the values of resistors R13 to R52 to increase the brightness of the displays. S1, D2 and R53 provide an artificial light for cases when there is not enough background light, as we explained earlier.

The power supply for the circuit is very simple. A 9 V battery powers the circuit, where a 7805 (IC9) is used to provide a stable 5 V to the controller.

Construction

A double-sided PCB has been designed for the circuit, and is shown in **Figure 4**. Populating this board isn't difficult, as long as you go about it the right way. First the component side has to be populated (so without the displays), with the exception of D1 and R4. You should



use two 4-pin SIL sockets for IC1 instead of a standard 8-pin IC socket, otherwise some of the pins of the displays will no longer be accessible for soldering! T1 and D2 have to be mounted at right angles to the board so that they can stick through the front of the case. Cut off the ends of the leads of C2, R6, R11 and the SIL sockets for IC1 as close as possible to the board, as they will otherwise get in the way when the displays are mounted.

For D1 you have to keep in mind that a 1V4 zener diode is similar to two ordinary diodes connected in series. The means that the connections are exactly the opposite of what you would expect; the band on the diode in this case corresponds to the anode). Photo transistor T1 (BPW40) looks similar to an LED; the longer leg is the collector.

The displays are mounted next. If the board has been populated according to the instructions, none of the display pins should be obstructed and they are easily soldered to the board. And finally it's the turn of D1 and R4. Bend their leads the right distance apart and cut them such that they lie neatly on the board. If they are too long they

will come into contact with the displays and it won't be possible to solder them neatly onto the board. D1 and R4 have to be soldered onto the component side of the board, since the solder side is obstructed by the displays. This doesn't matter, since the PCB has plated-through holes.

You are of course free to choose your own enclosure. However, the PCB has been designed to fit into an EG1530B made by Bopla, although there are likely to be many other suitable enclosures.

Operation and test

When the PCB has been fully populated and checked we can start testing its operation.

First the rev counter has to be switched on, after which all displays should show a '-' sign.

If we then hold the sensor near a burning incandescent lamp, the display should show a value in the region of 3000 RPM after about a second. This is not an error, but a consequence of the fact that an incandescent lamp flickers with a frequency of 100 Hz when it is connected to the 50 Hz mains supply. The sensor therefore 'sees' a frequency of 100 Hz. The rev counter is initialised for use with a two-bladed propeller when it is switched on. Using these figures in the formula:

$$RPM = frequency \times 60 / number\ of\ blades,$$
 this gives:

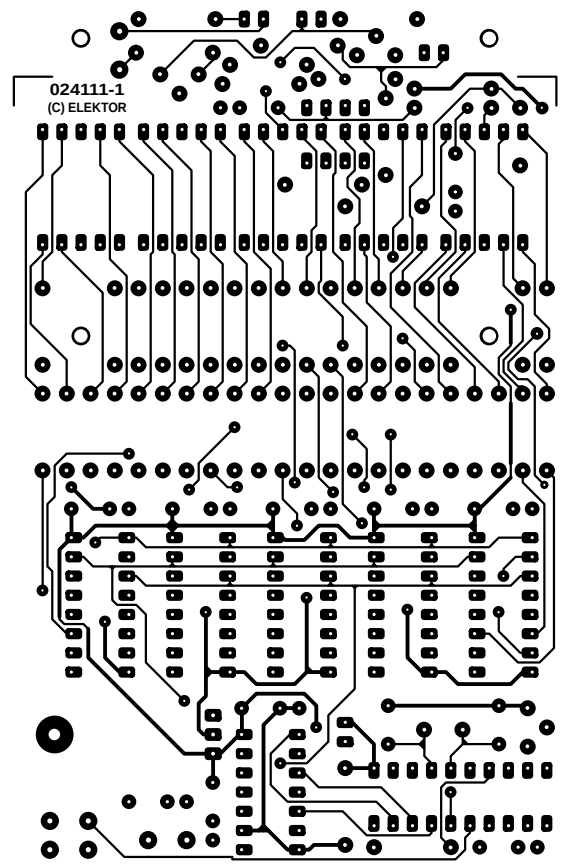
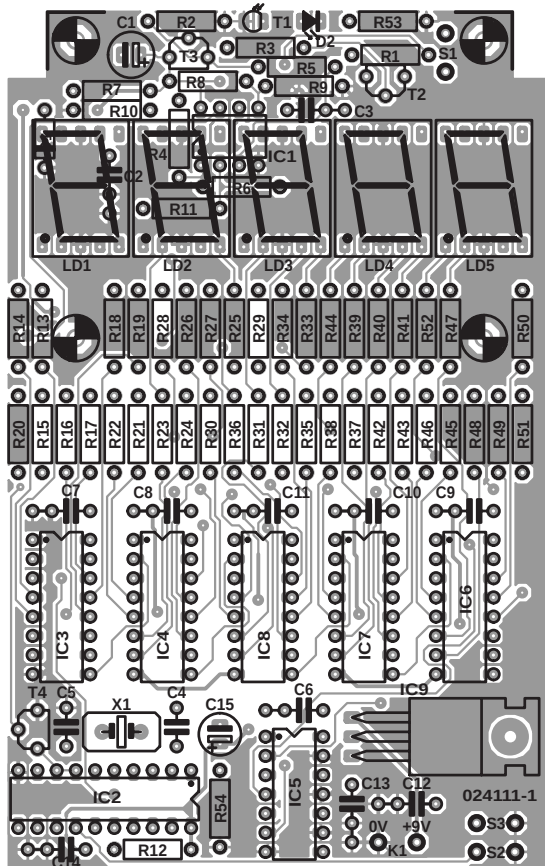


Figure 4. A well-arranged double-sided PCB has been designed for the rev counter.

$$RPM = 100 \text{ Hz} \times 60 / 2 = 3000 \text{ RPM}$$

Pressing the button with the '+' causes the number of propeller blades to increase by

one. The button with the '-' obviously does the exact opposite. The controller only looks at these buttons

once per second, so it may not react immediately when you press a button. If you hold a button down longer, the setting will change by one every second. Every time that the controller changes the number of blades, this will be shown on the display as —X—, where 'X' is the current number of propeller blades.

If it has passed all tests, it's become time to try the rev counter on a real model airplane. First, set the rev counter to the right number of blades for the propeller. Start the engine of the airplane as usual (hopefully in a safe manner!) and let somebody else hold it for you. Hold the sensor in front of the blades such that the blades throw a shadow on the sensor at every revolution. **Take great**

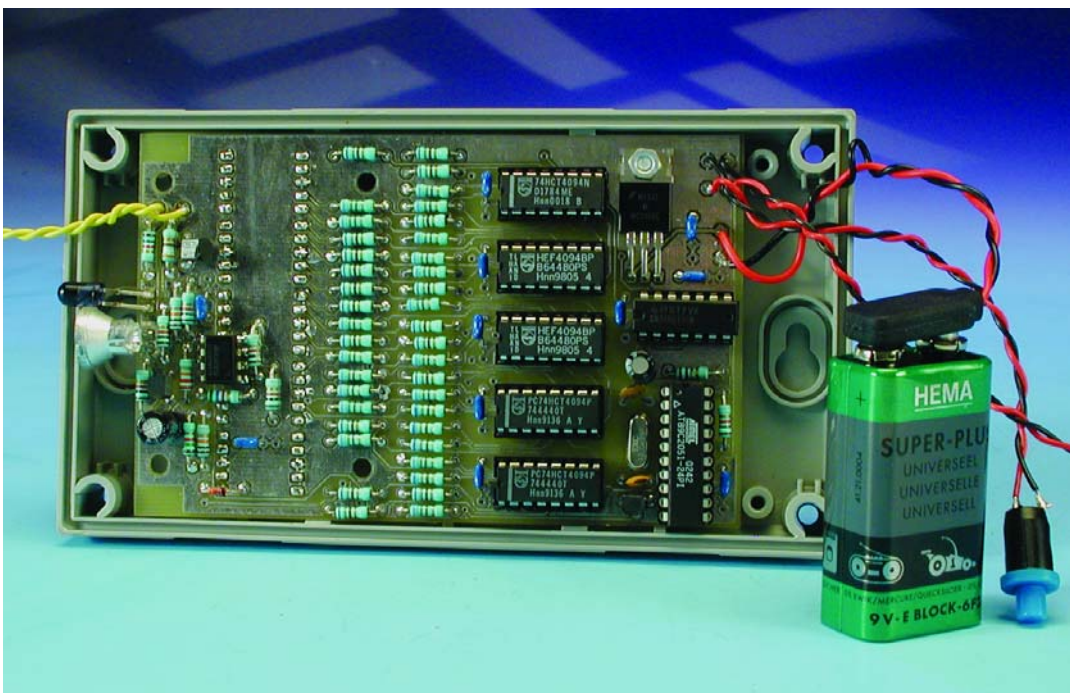


Figure 5. The component side of a fully assembled board.

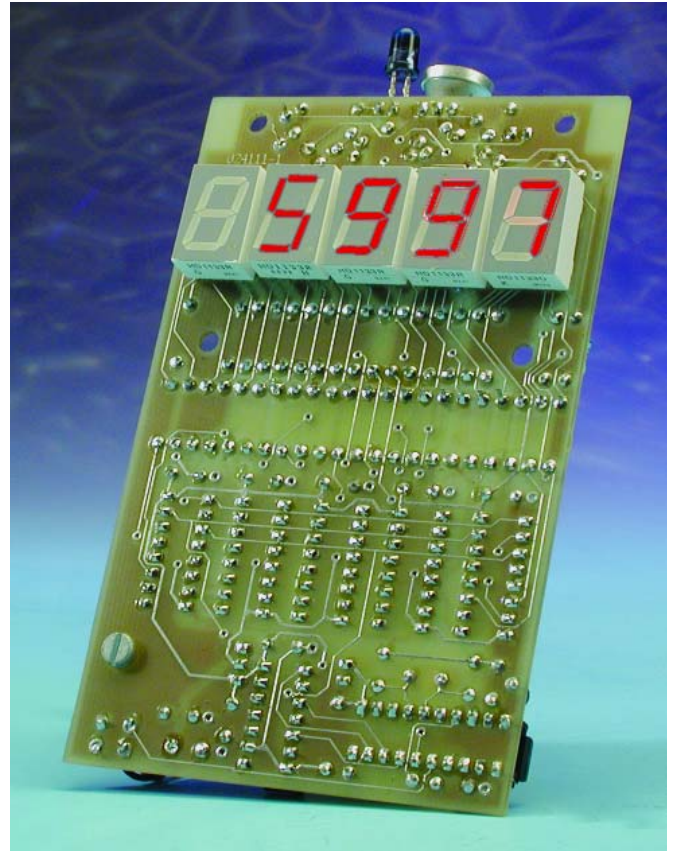
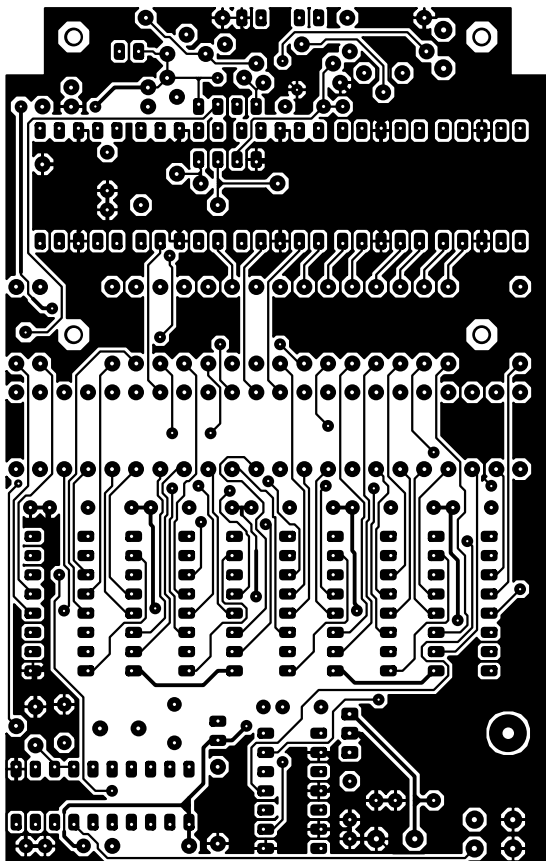


Figure 6. The five displays are mounted on the solder side of the board.

COMPONENTS LIST

Resistors:

R1 = 390Ω
R2,R3,R6,R9,R11,R12,R53,R54 = 1kΩ
R4 = 5kΩ
R5,R10 = 10kΩ
R7 = 1kΩ
R8 = 22kΩ
R13-R52 = 680Ω

Capacitors:

C1 = 220μF 16V radial
C2,C3,C6-C14 = 100nF
C4,C5 = 22pF
C15 = 10μF 16V radial

Semiconductors:

D1 = zener diode 1.4V 500mW
D2 = IR LED (e.g., LD271)
IC1 = TLC272CP
IC2 = 89C2051-12PC, programmed,
order code **024111-41** (see Readers

Services page)

IC3,IC4,IC6,IC7,IC8 = 74HCT4094
IC5 = 74HC04
IC9 = 7805
LD1-LD5 = HD1133 O-K
T1 = BPW40
T2 = BC557
T3,T4 = BC547

Miscellaneous:

K1 = 9-V battery clip
S1,S2,S3 = pushbutton, 1 make
contact
X1 = 12MHz quartz crystal
Enclosure: Bopla EGI 530B
PCB, order code **024111-1** (see
Readers Services page)
Disk, contains source- and hex code,
order code **024111-11** (see Readers
Services page)

care that the circuit does not come into contact with the rotating propeller. This could be very dangerous, since the power present in even a small propeller shouldn't be

underestimated! A measurement will now be taken at about one-second intervals and the display will show the exact engine speed. If this is not the case, you can turn on the

IR LED by pressing push-button S1. This emits infrared light, which is invisible, but which the sensor certainly reacts to. In this way, a measurement can still be taken in weak light!

Other applications

The use of the rev counter is not restricted to measuring propeller speeds. In principle it can be used to measure anything that produces a fast-changing light intensity, as long as there is a big enough difference between the light and dark periods. The display will still show a figure in RPM, which has to be converted into a frequency. To simplify this, the circuit should be set to use six blades, when the display will show the frequency multiplied by 10 (for the previously mentioned incandescent light with a frequency of 100 Hz this will be shown as 1000 on the display).

In this way it would be possible to measure the frame-rate of your computer monitor. The best contrast between light and 'shadow' is obtained when the monitor shows a white screen. Should the rev counter give an obviously incorrect value, you can try increasing the brightness of the monitor.

(024111-1)